AIRS V5 Validation: Preliminary Case Study

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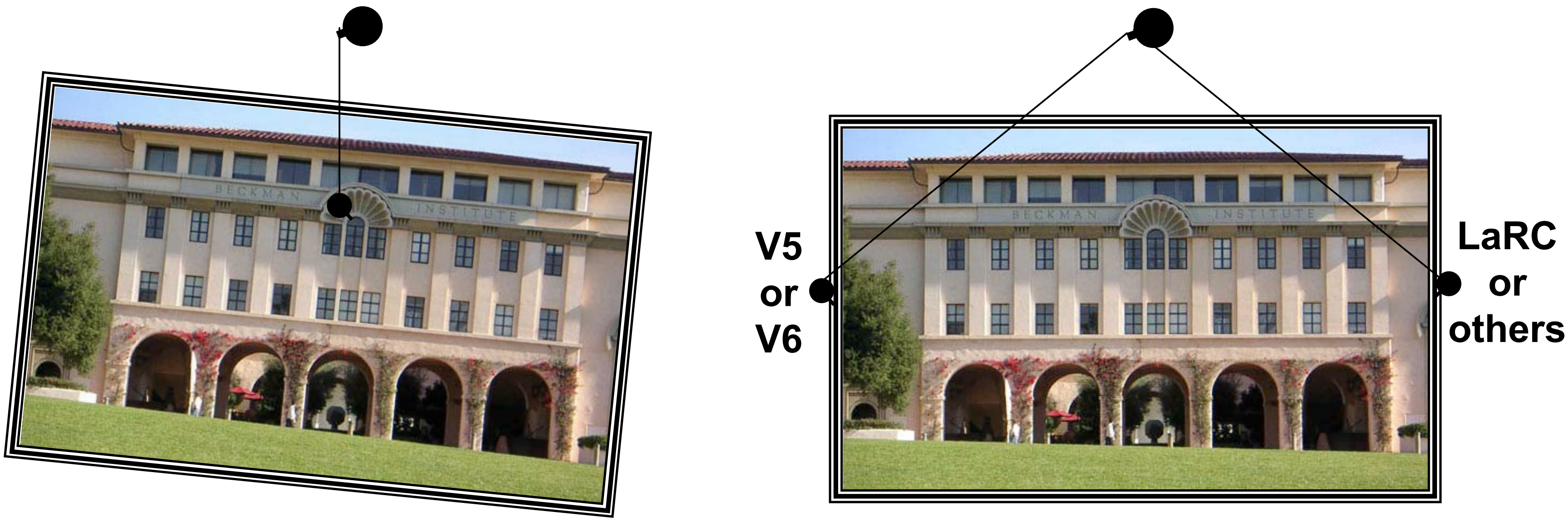
Introduction…



An alternative retrieval algorithm can be of assistance to validate retrieval algorithm and its products and to know if retrievals reach the instrument potential.

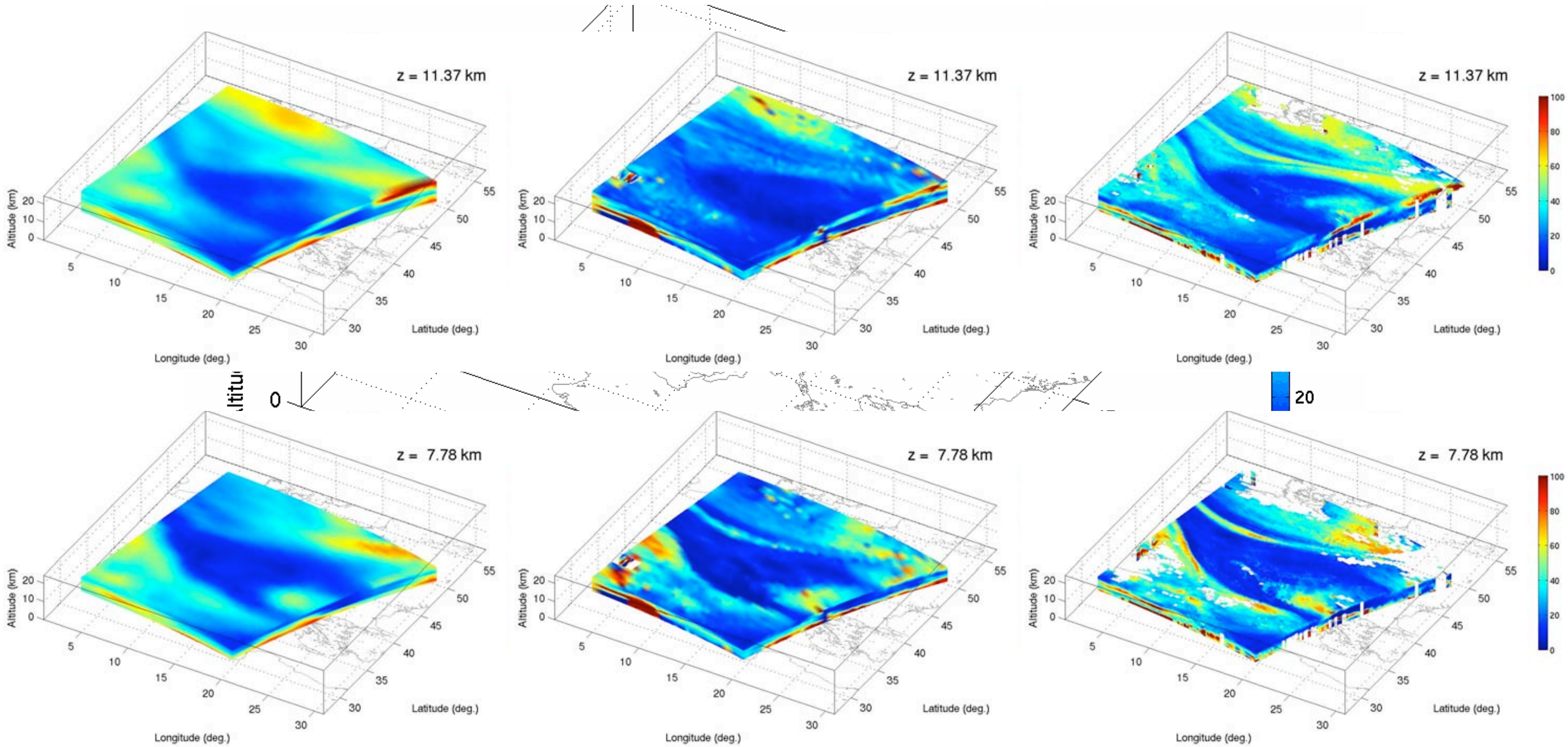
Equivalent Spatial Resolution Needed

AIRS Case 2004.09.08 Granule 011 (relative humidity field)

ECMWF doesn't have a spatial resolution needed for precisely validating AIRS retrievals.

LaRC Clear Algorithm (regional training) using AIRS V4 CC Radiance (3x3 FOVs).

LaRC Cloudy Algorithm (global training) using AIRS original radiance (1x1 FOV).



Outline

- LaRC Retrieval Algorithm Introduction
- AIRS and IASI Retrieval Demonstration
- AIRS and IASI Inter-comparison using LaRC Retrieval Algorithm
- AIRS V5 and LaRC Retrieval Inter-comparison
- Validation with Dropsonde and Radiosonde
- Summary, Future Work, and Suggestion

LaRC Single FOV Retrieval Algorithm

PART A: REGRESSION RETRIEVAL (Zhou et al., GRL 2005)

Using an all-seasonal-global training database to diagnose 0-2 cloud layers from training relative humidity profile:

A single cloud layer is inserted into the input training profile. Approximate lower level cloud using opaque cloud representation.

Use parameterization of balloon and aircraft cloud microphysical data base to specify cloud effective particle diameter and cloud optical depth:

Different cloud microphysical properties are simulated for same training profile using random number generator to specify visible cloud optical depth within a reasonable range. Different habitats can be specified (Hexagonal columns assumed here).

Use LBLRTM/DISORT "lookup table" to specify cloud radiative properties:

Spectral transmittance and reflectance for ice and liquid clouds interpolated from multi-dimensional look-up table based on DISORT multiple scattering calculations.

Compute EOFs and Regressions from clear, cloudy, and mixed radiance data base:

Regress cloud, surface properties & atmospheric profile parameters against radiance EOFs.

PART B: 1-D VAR PHYSICAL RETRIEVAL (Zhou et al., JAS 2007)

A one-dimensional (1-d) variational solution with the regularization algorithm (i.e., the minimum information method) is chosen for physical retrieval methodology which uses the regression solution as the initial guess.

Cloud optical/microphysical parameters, namely effective particle diameter and visible optical thickness, are further refined with the radiances observed within the 10.4 μm to 12.5 μm window region.

LaRC Single FOV Retrieval Algorithm

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Thermodynamic and cloud parameter retrieval using infrared spectral data

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[1] High-resolution infrared radiance spectra obtained from near nadir observations provide atmospheric, surface, and cloud property information. A fast radiative transfer model, including cloud effects, is used for atmospheric profile and cloud parameter retrieval. The retrieval algorithm is presented along with its application to recent field experiment data from the NPOESS Airborne Sounder Testbed – Interferometer (NAST-I). The retrieval accuracy dependence on cloud properties is discussed. It is shown that relatively accurate temperature and moisture retrievals can be achieved below optically thin clouds. For optically thick clouds, accurate temperature and moisture profiles down to cloud top level are obtained. For both optically thin and thick cloud situations, the cloud top height can be retrieved with an accuracy of approximately 1.0 km. Preliminary NAST-I retrieval results from the recent Atlantic-THORPEX Regional Campaign (ATReC) are presented and compared with coincident observations obtained from dropsondes and the nadir-pointing Cloud Physics Lidar (CPL). **Citation:** Zhou, D. K., W. L. Smith, X. Liu, A. M. Larar, H.-L. A. Huang, J. Li, M. J. McGill, and S. A. Mango (2005), Thermodynamic and cloud parameter retrieval using infrared spectral data, *Geophys. Res. Lett.*, *32*, L15805, doi:10.1029/2005GL023211.

1. Introduction

[2] Observations from an aircraft or a spacecraft flown infrared instrument can be used to infer the atmospheric temperature, moisture, and concentration of other chemical species using radiative transfer equation inversion techniques. The retrievals of atmospheric state (i.e., temperature and moisture profiles) obtained from infrared radiometric measurements will contain intolerable error near and below the cloud level if the attenuation of infrared radiation emitted from the Earth's surface and the atmosphere below the clouds is not properly accounted for in the retrieval process. Since there are vast cloudy regions of the globe, a great deal of effort has gone into the cloud detection and cloud-clearing processes [*Smith et al.*, 2004]. Nevertheless, the schemes dealing with cloud detection and cloud-clearing [*Smith*, 1968] remain a major source of error in the final retrieval products. Recently, fast molecular and cloud transmittance models have been developed to enable the infrared radiances to be used under cloudy conditions with the accuracy required for sounding retrieval processing. Here, the EOF (i.e., empirical orthogonal function) statistical regression retrieval algorithm [e.g., *Smith and Woolf*, 1976; *Zhou et al.*, 2002] is expanded to include realistic cloud parameters (e.g., cloud top height, effective particle diameter, and optical depth) to deal with cloudy as well as cloud-free observations. With this improved algorithm, cloud parameters, as well as atmospheric profiles, are retrieved from the spectral radiance observations.

[3] The NPOESS (National Polar-orbiting Operational Environmental Satellite System) Airborne Sounder Testbed – Interferometer (NAST-I) has been successfully operating on high altitude aircraft since 1998 [e.g., *Cousins and Smith*, 1997; *Smith et al.*, 2005]. NAST-I is designed to support the development of future satellite temperature and moisture sounders such as the IASI (Infrared Atmospheric Sounding Interferometer) on the METOP satellite, the CrIS (Cross-track Infrared Sounder) on the NPP (NPOESS Preparatory Project) and the following NPOESS series of satellites, as well as the HES (Hyperspectral Environmental Suite) to fly on the GOES-R satellite series. Both simulated and measured NAST-I data are used in this study. The retrieval accuracy, which depends on cloudiness, is discussed. Retrievals of cloud properties and atmospheric properties from NAST-I observations are compared with coincident observations obtained from the nadir-pointing Cloud Physics Lidar (CPL) and dropsondes, respectively.

2. Radiance Simulations, Training, and Regression

[4] The infrared radiances measured under cloudy conditions are simulated by combining the Optimal Spectral Sampling (OSS) fast molecular radiative transfer model [*Moncet et al.*, 2003], with the physically-based cloud radiative transfer model based on DIScrete Ordinate Radiative Transfer (DISORT) [*Stamnes et al.*, 1988] calculations performed for a wide variety of cloud microphysical properties [e.g., *Yang et al.*, 2001]. Here, a maximum of 2 cloud levels is used; a single cloud layer (either ice or liquid) and another optically thick cloud layer can be assumed to exist at a lower level when the radiosonde detects two, or more, layers of cloud. These cloud layers, along with the radiosonde profile, are used to simulate NAST-I radiances. Cirrus clouds are assumed to exist at the

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Physically Retrieving Cloud and Thermodynamic Parameters from Ultraspectral IR Measurements

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ABSTRACT

A physical inversion scheme has been developed dealing with cloudy as well as cloud-free radiance observed with ultraspectral infrared sounders to simultaneously retrieve surface, atmospheric thermodynamic, and cloud microphysical parameters. A fast radiative transfer model, which applies to the clouded atmosphere, is used for atmospheric profile and cloud parameter retrieval. A one-dimensional (1D) variational multivariable inversion solution is used to improve an iterative background state defined by an eigenvector-regression retrieval. The solution is iterated in order to account for nonlinearity in the 1D variational solution. It is shown that relatively accurate temperature and moisture retrievals can be achieved below optically thin clouds. For optically thick clouds, accurate temperature and moisture profiles down to cloud-top level are obtained. For both optically thin and thick cloud situations, the cloud-top height can be retrieved with relatively high accuracy (i.e., error <1 km). National Polar-orbiting Operational Environmental Satellite System (NPOESS) Airborne Sounder Testbed Interferometer (NAST-I) retrievals from the The Observing-System Research and Predictability Experiment (THORPEX) Atlantic Regional Campaign are compared with coincident observations obtained from dropsondes and the nadir-pointing cloud physics lidar (CPL). This work was motivated by the need to obtain solutions for atmospheric soundings from infrared radiances observed for every individual field of view, regardless of cloud cover, from future ultraspectral geostationary satellite sounding instruments, such as the Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS). However, this retrieval approach can also be applied to the ultraspectral sounding instruments to fly on polar satellites, such as the Infrared Atmospheric Sounding Interferometer (IASI) on the European MetOp satellite, the Cross-track Infrared Sounder (CrIS) on the NPOESS Preparatory Project, and the follow-on NPOESS series of satellites.

1. Introduction

Nadir observations from a spacecraft- or an aircraft-flown infrared instrument can be used to infer the atmospheric temperature, moisture, and concentration of other chemical species using radiative transfer equation inversion techniques. The retrievals of atmospheric state, temperature, and moisture profiles obtained from infrared radiometric measurements will contain intolerable error near and below the cloud level if the cloud radiation and the attenuation of infrared radiation emitted from the earth's surface and the atmosphere

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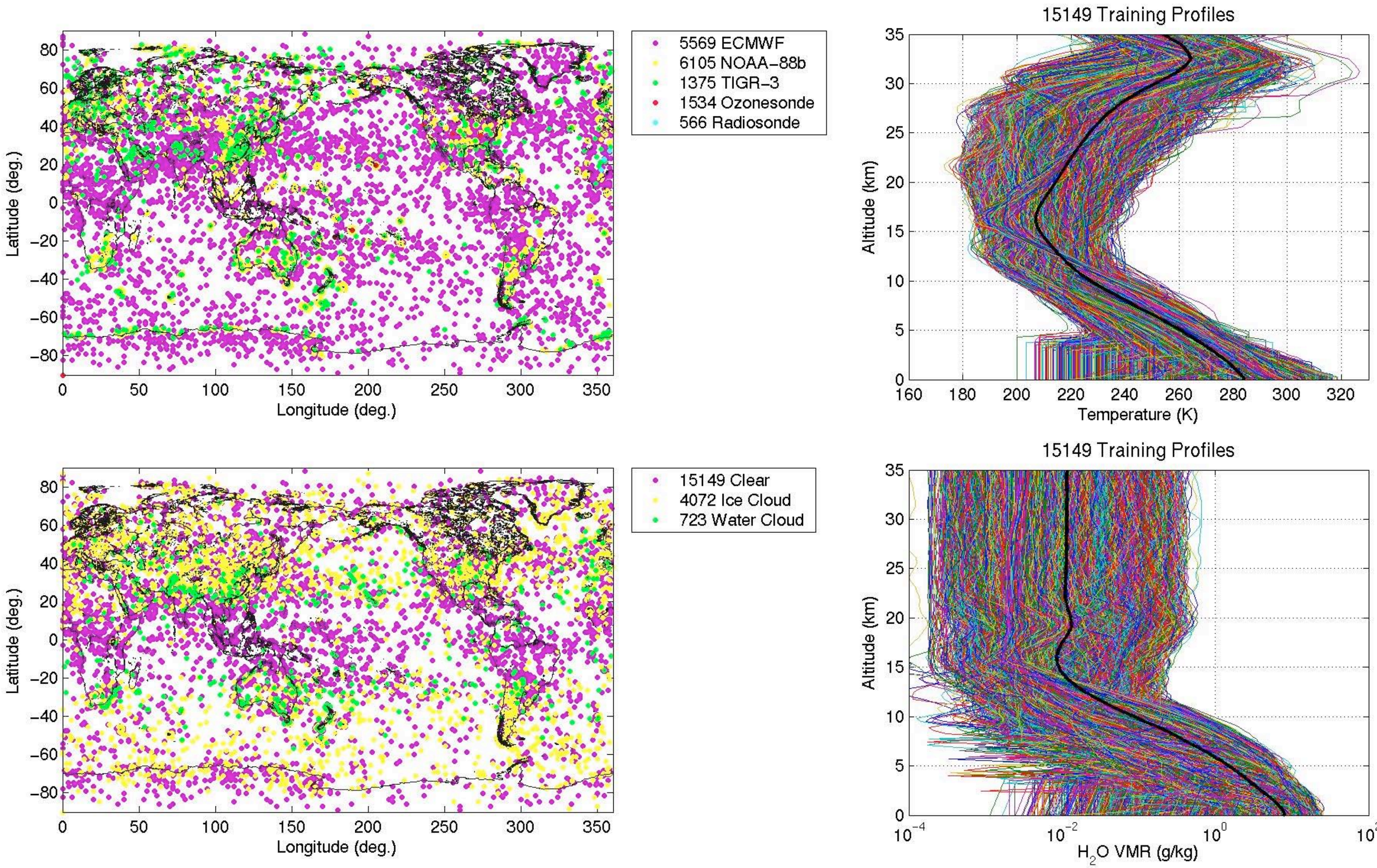
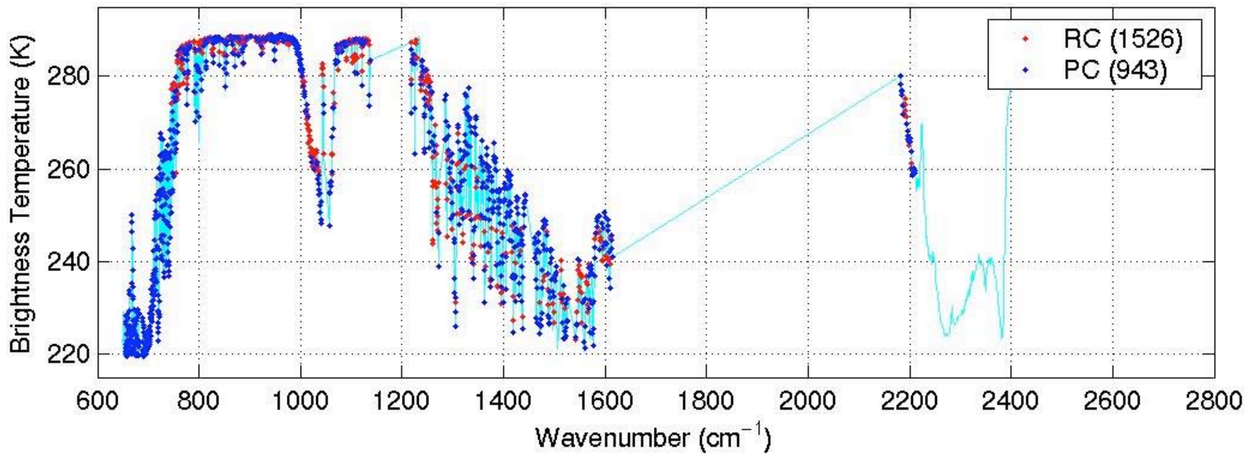
Global Training for LaRC Algorithm

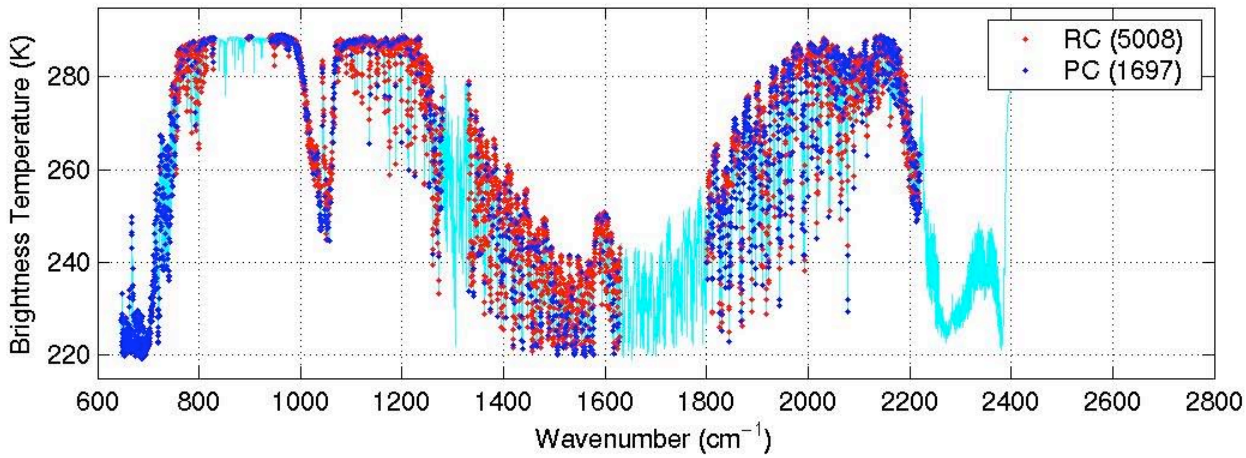


Channel Used in LaRC Retrieval Algorithm

AIRS: 1526 channels for regression, 943 channels for physical retrieval

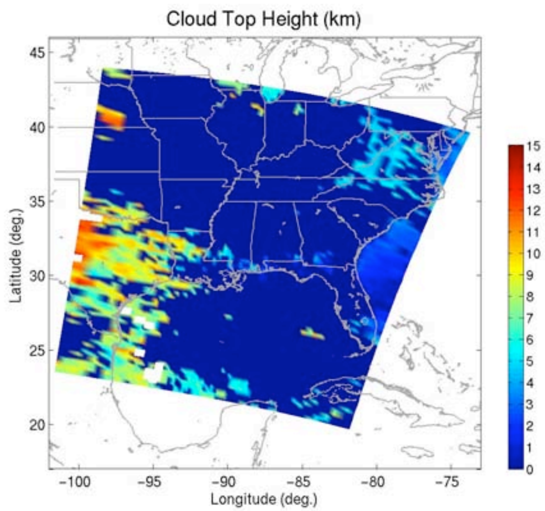


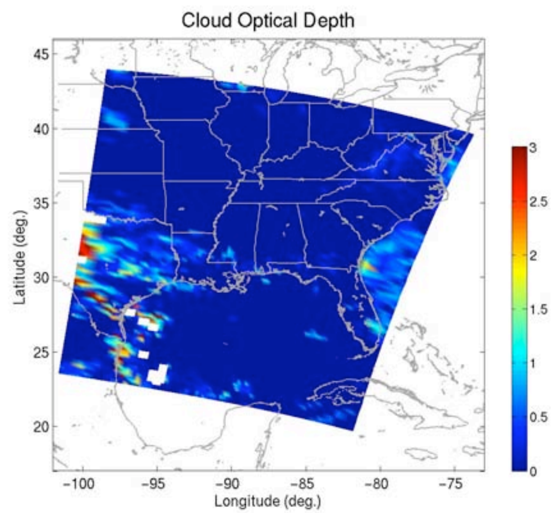
IASI: 5008 channels for regression, 1697 channels for physical retrieval

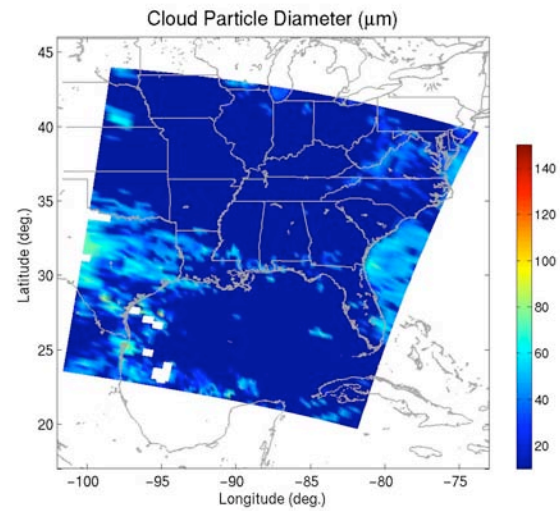


LaRC Retrieval Demo with IASI: Cloud & Surface

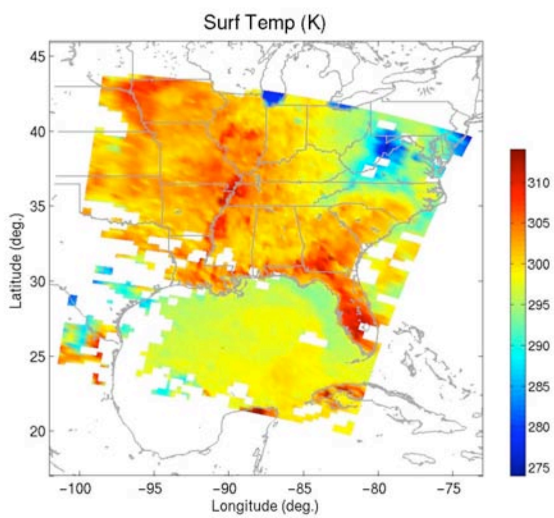
Cloud Parameters:

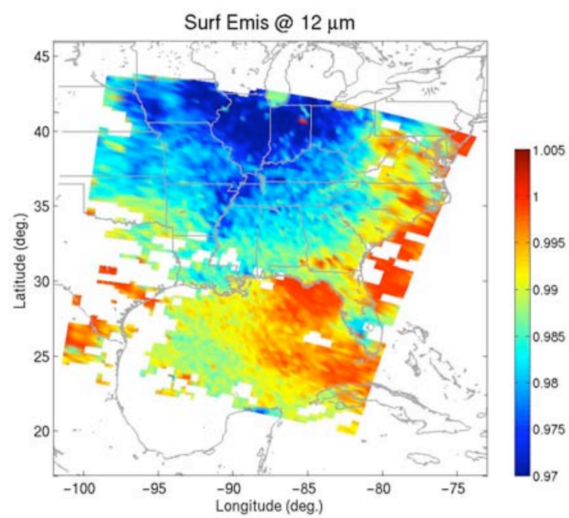


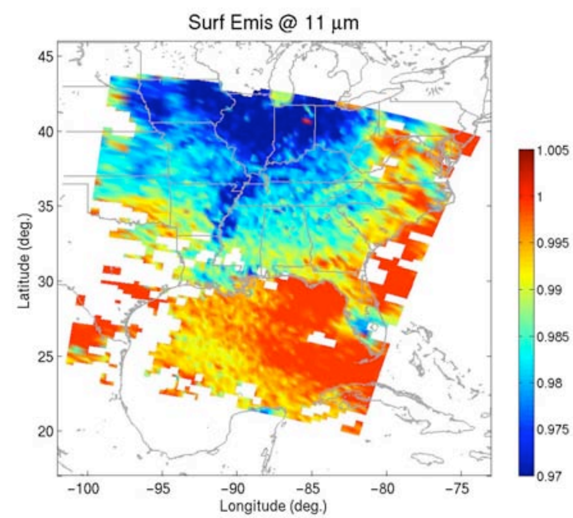




Surface Properties:







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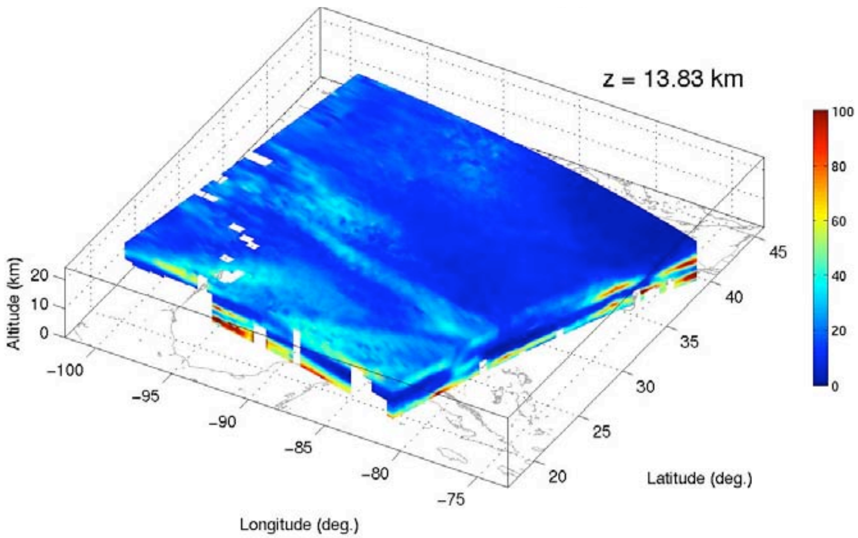
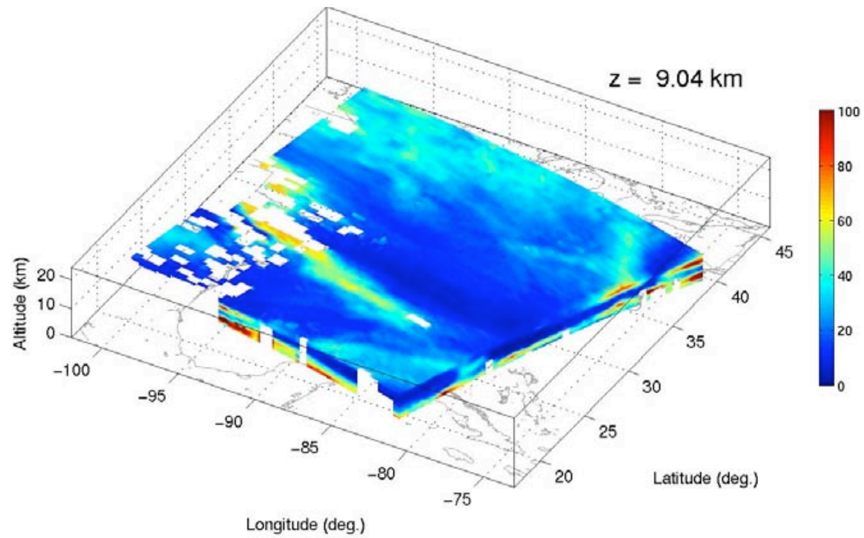
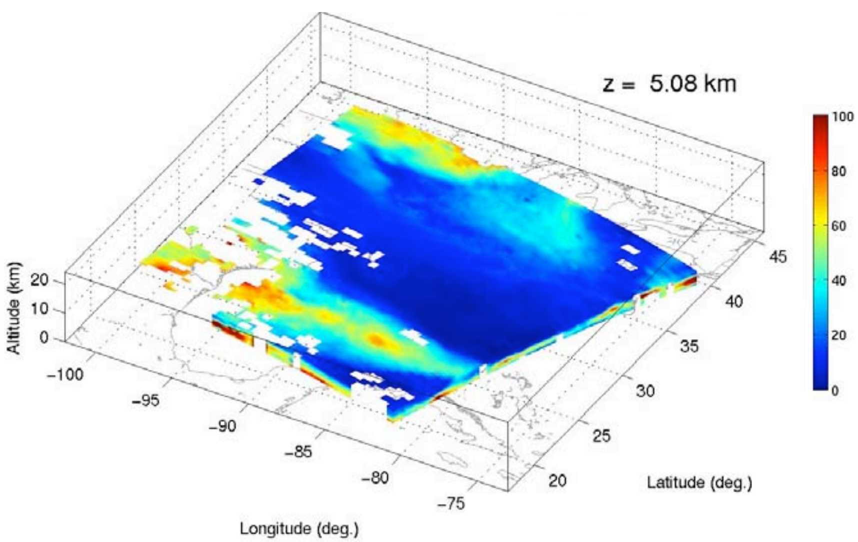
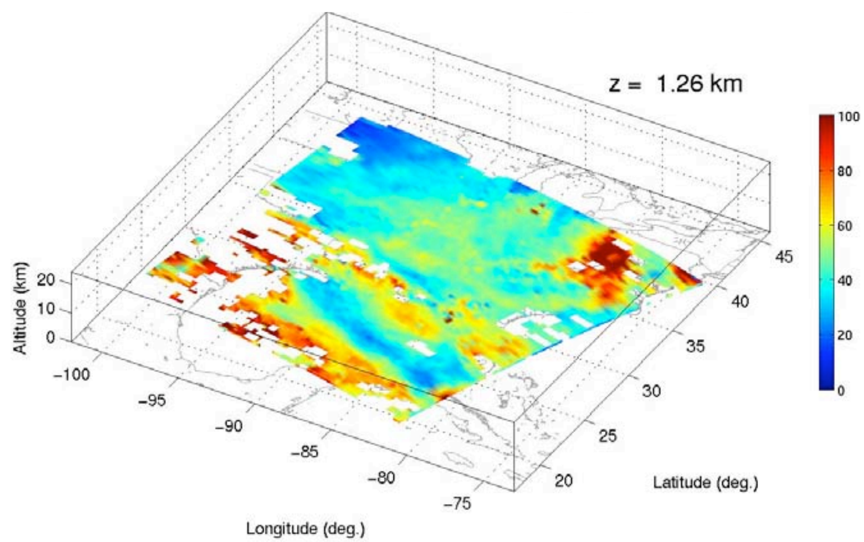
LaRC Retrieval Demo with IASI: RH Horizontal

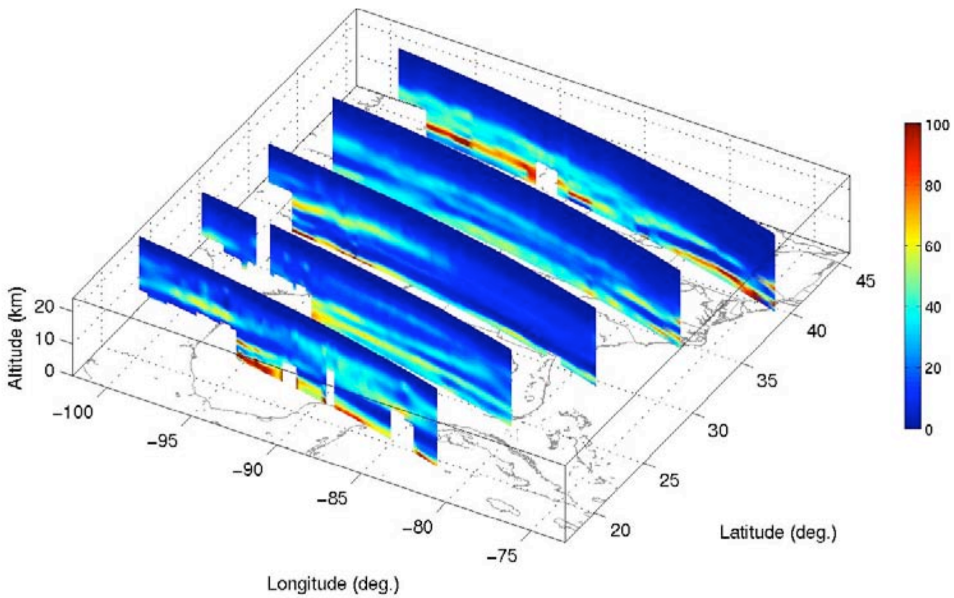


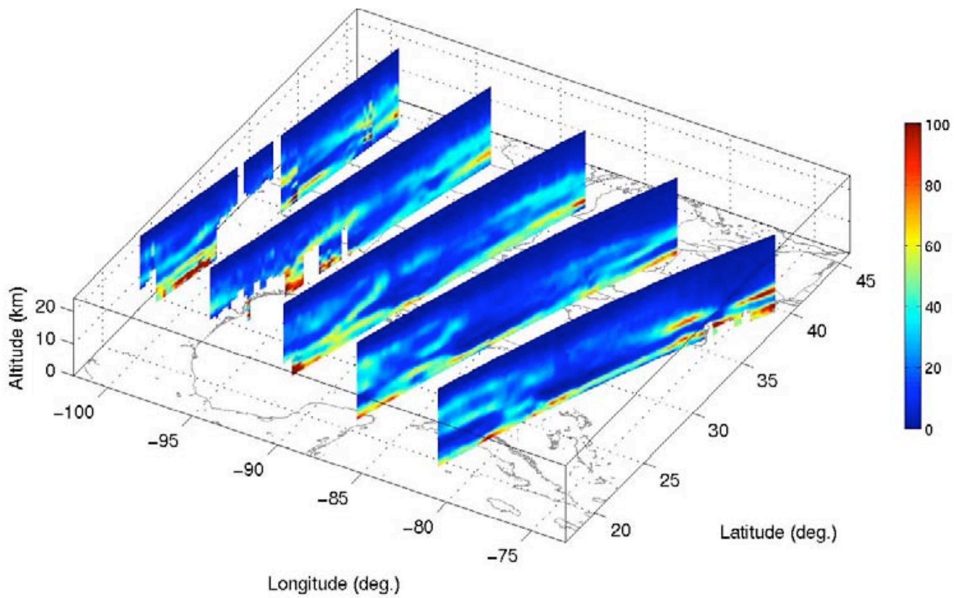






LaRC Retrieval Demo with IASI: RH Vertical

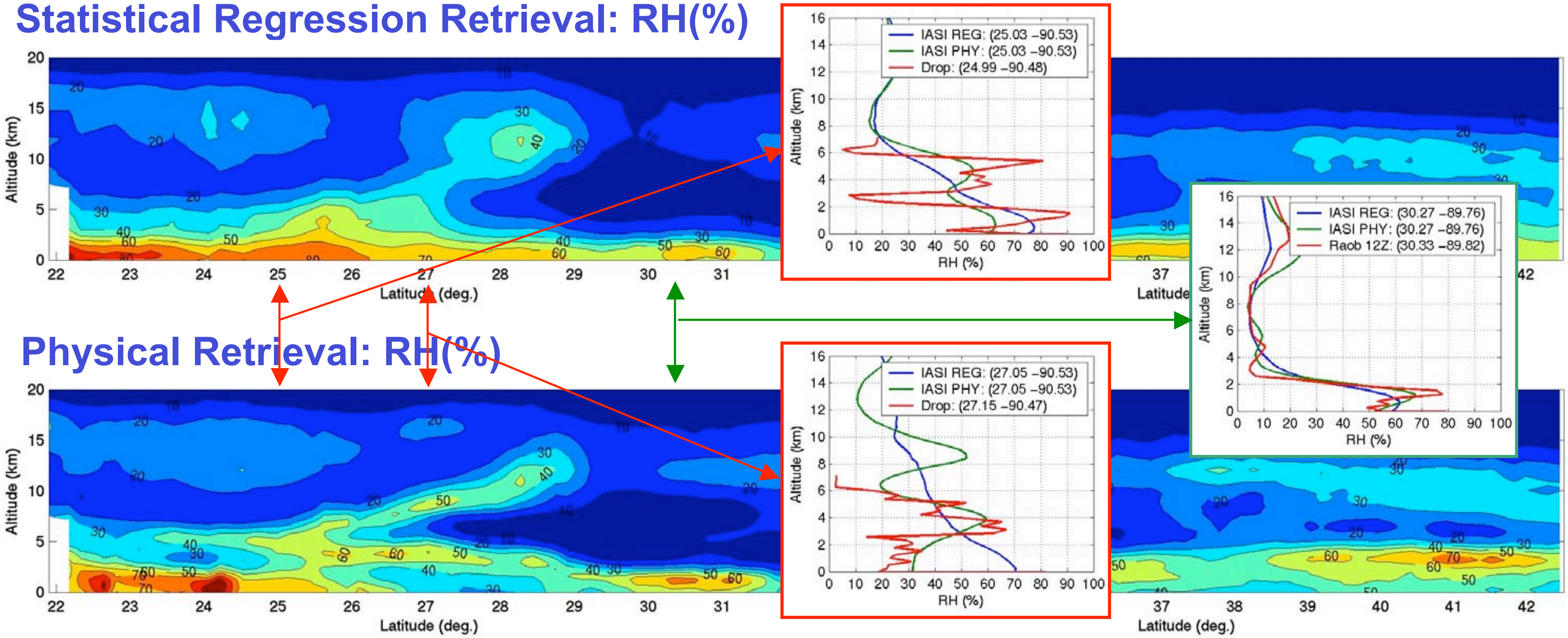




LaRC IASI Regression vs. Physical Retrieval

Statistical Regression Retrieval: RH(%)

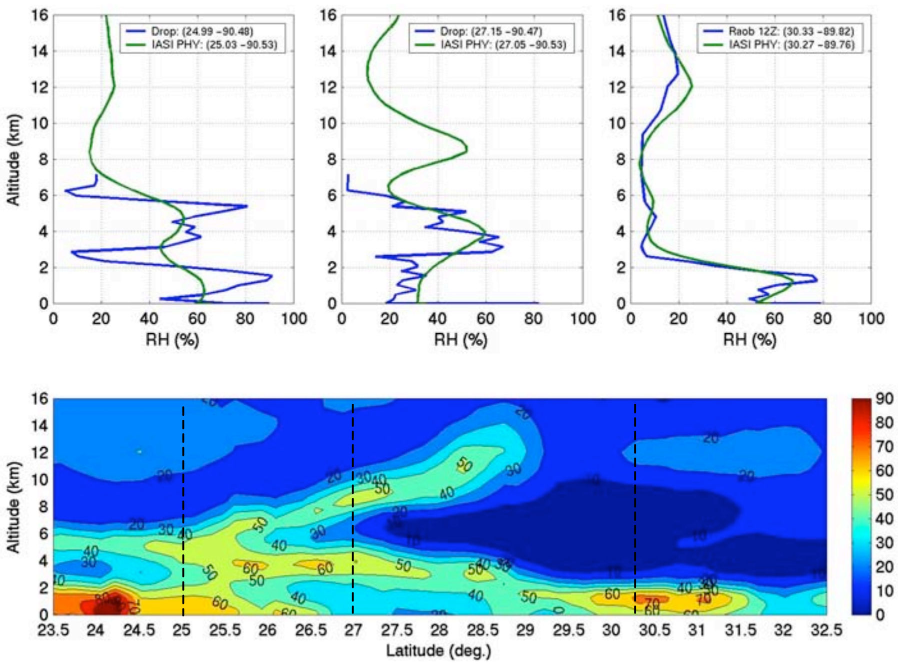
Physical Retrieval: RH(%)



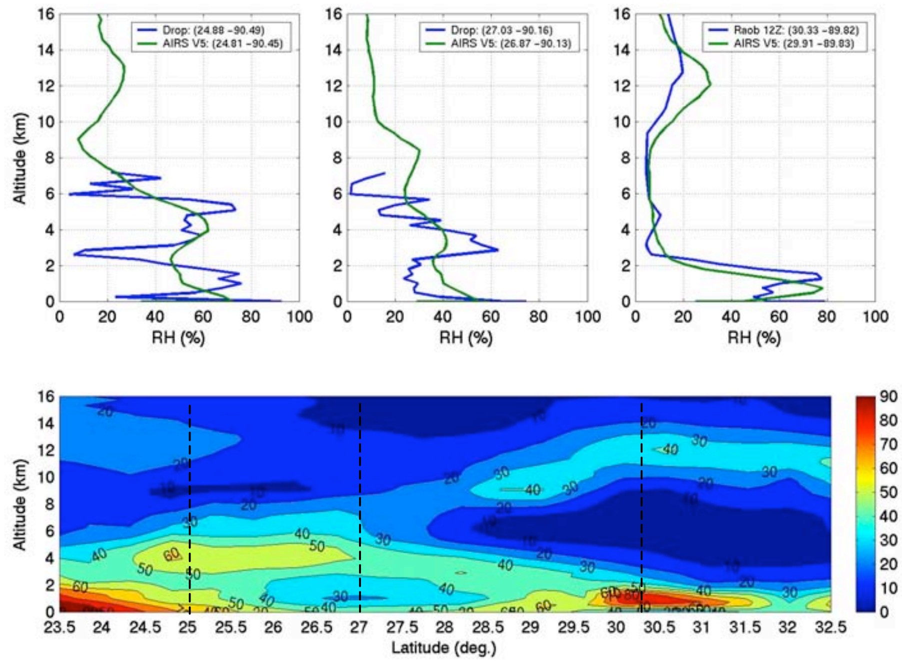
The retrieval improvement based on the EOF statistical regression through physical iteration is only contributed by IASI measurements as the minimum information methodology used. A high resolution atmospheric structure is captured very well by IASI measurements (retrievals); not only in the troposphere but also in the boundary layer.

Comparison between IASI and AIRS

IASI LaRC Retrieval:
101 vertical grid & IASI 1x1 FOVs



AIRS V5 Retrieval:
101 vertical grid & AIRS 3x3 FOVs



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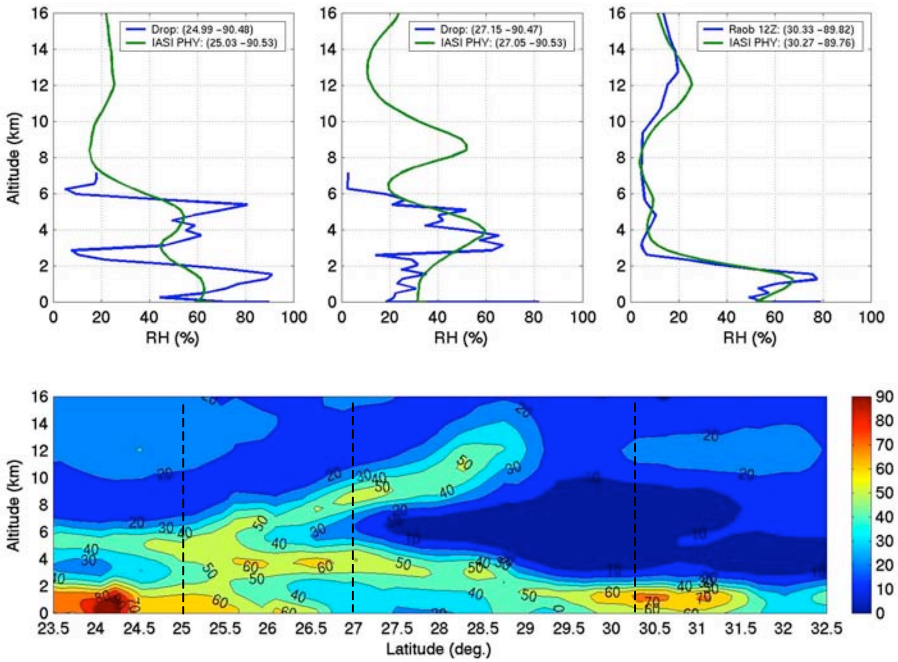
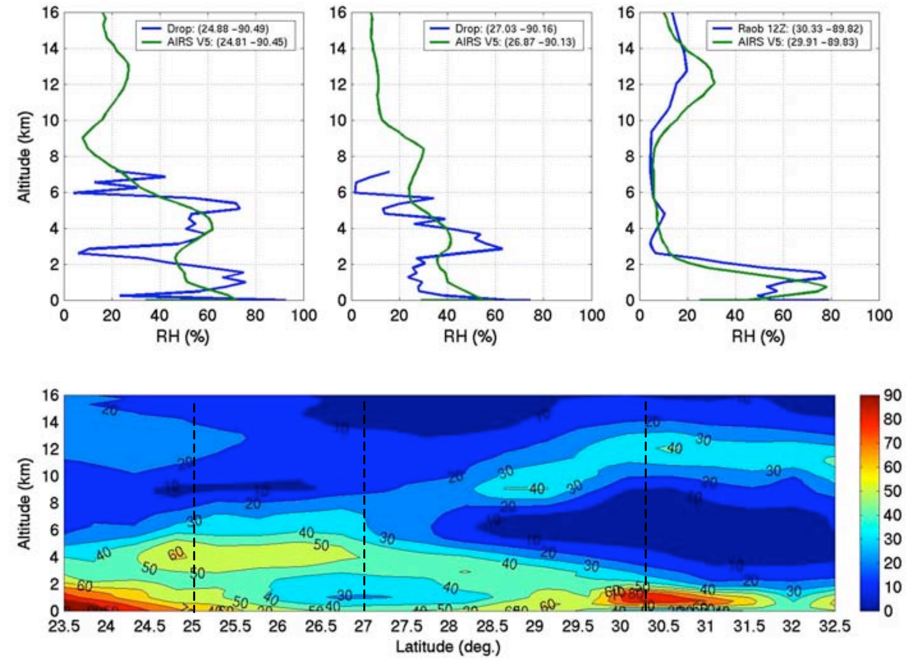
Why they are different?

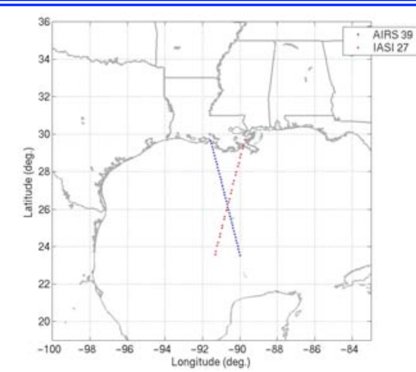
IASI LaRC Retrieval: 101 vertical grid & IASI 1x1 FOVs



AIRS V5 Retrieval: 101 vertical grid & AIRS 3x3 FOVs

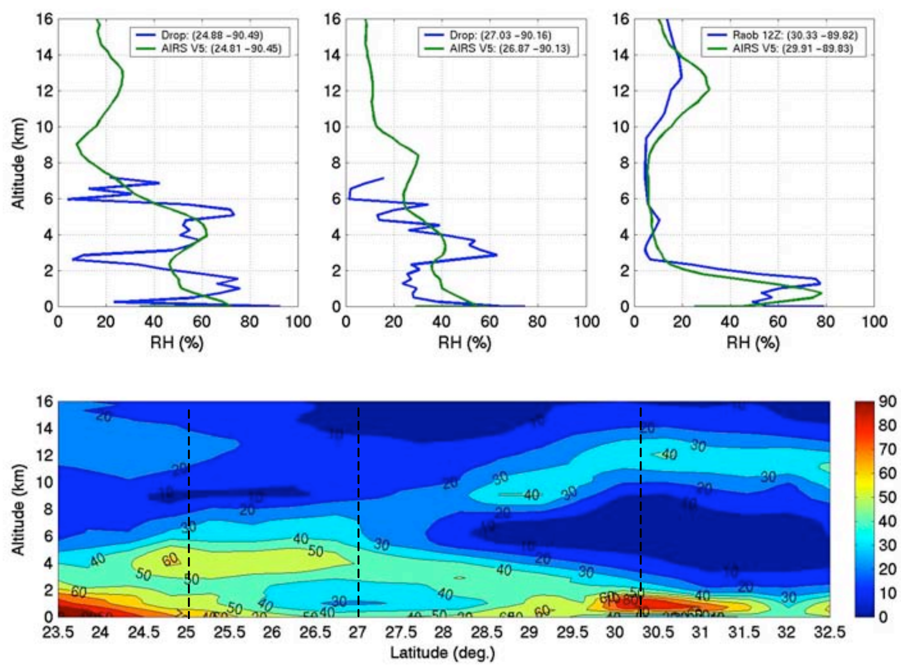


1. Different Instruments (e.g., spectral resolution, noise level).
2. Different Obs. Location and Times (i.e., IASI@15:45UTC, AIRS@19:30UTC).
3. Different Resolutions (e.g., vertical and horizontal).
4. Different Retrieval Algorithms.
5. others...?

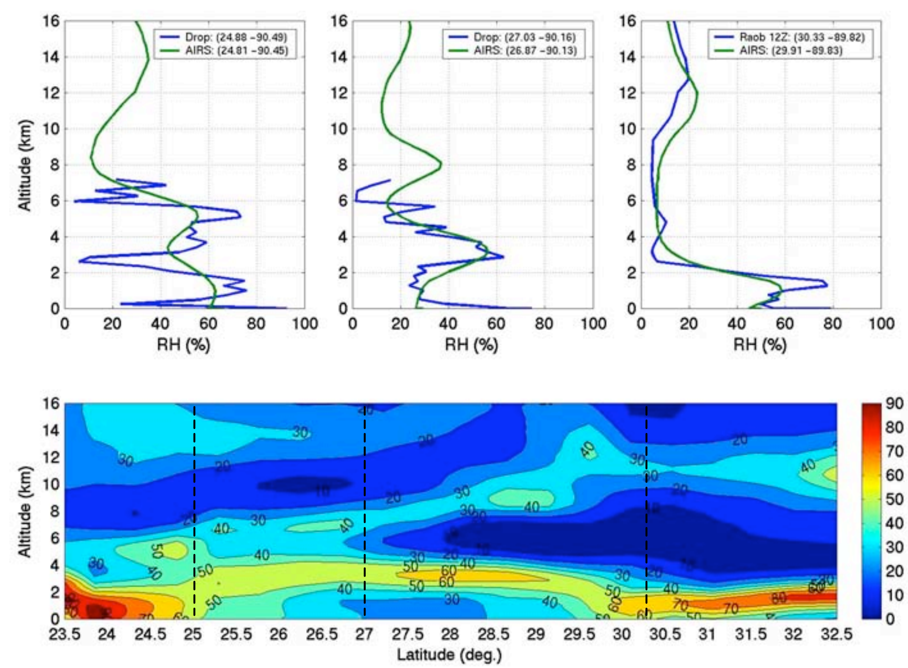


Difference between the Algorithms

AIRS V5 Retrieval: 101 vertical grid & AIRS 3x3 FOVs

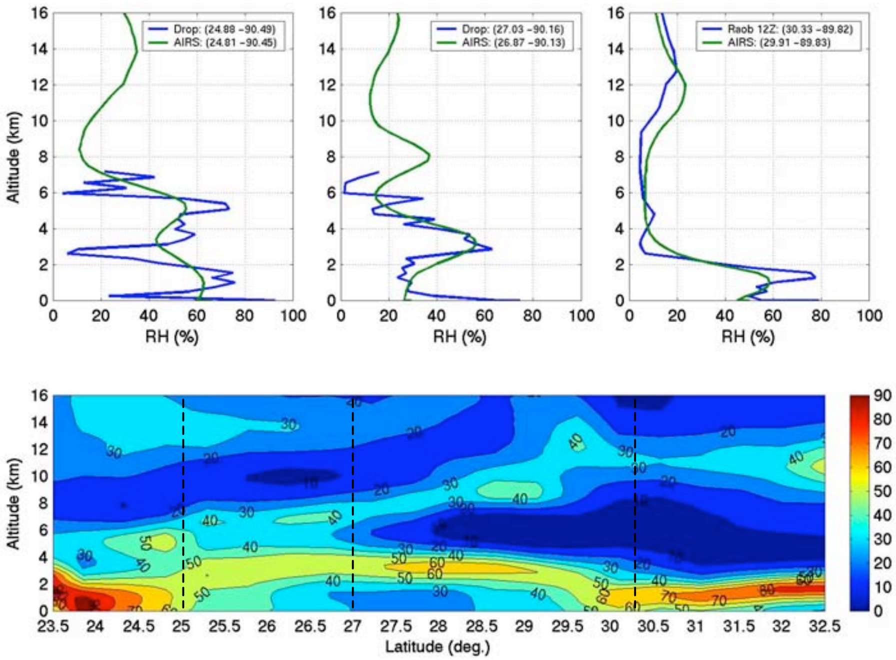


AIRS LaRC Retrieval: 101 vertical grid & AIRS 3x3 FOVs

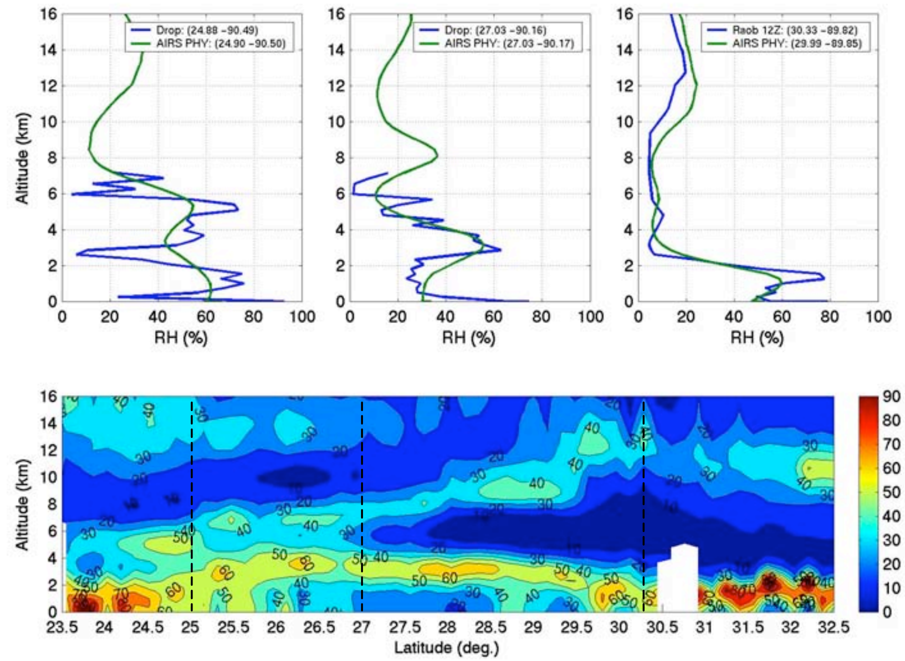


Difference between the Horizontal Resolution

AIRS LaRC Retrieval: 101 vertical grid & AIRS 3x3 FOVs

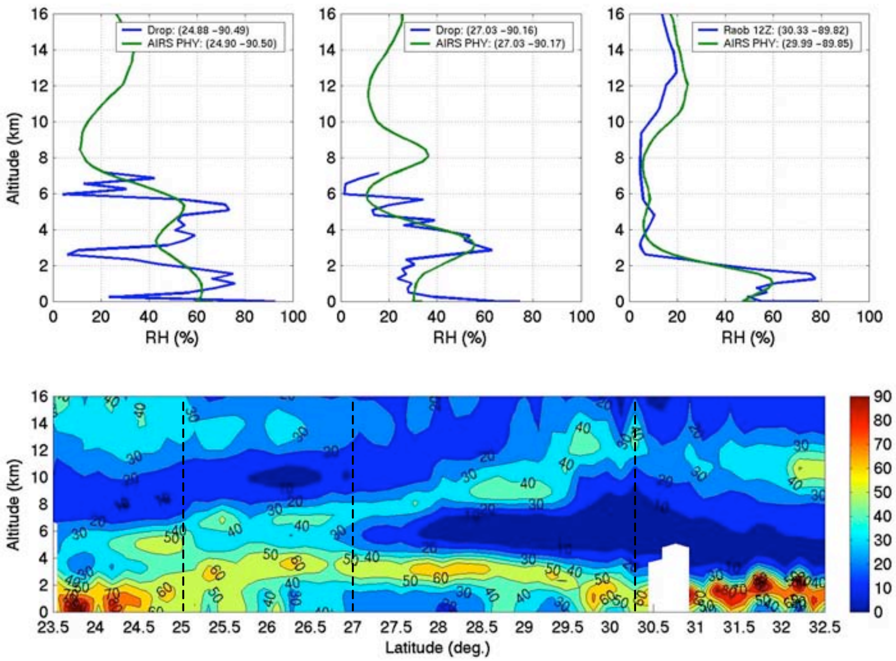


AIRS LaRC Retrieval: 101 vertical grid & AIRS 1x1 FOVs

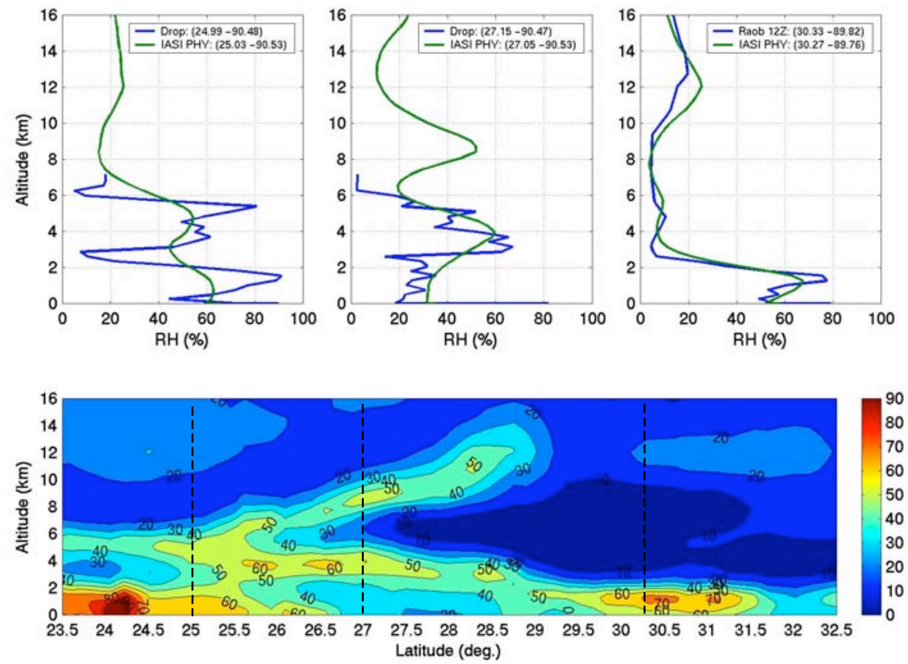


Difference between IASI and AIRS & their Obs.

AIRS LaRC Retrieval: 101 vertical grid & AIRS 1x1 FOVs



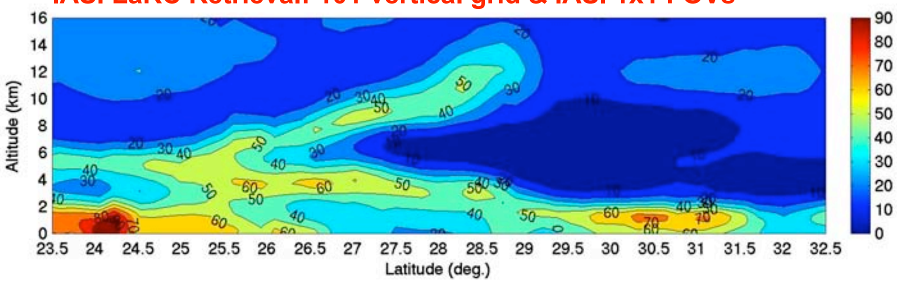
IASI LaRC Retrieval: 101 vertical grid & IASI 1x1 FOVs



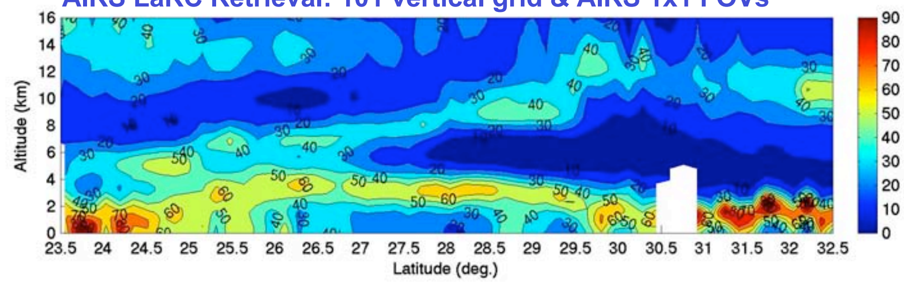
AIRS vs. IASI & V5 vs. LaRC (RH Vertical)

Different Instruments, Same Algorithm

IASI LaRC Retrieval: 101 vertical grid & IASI 1x1 FOVs

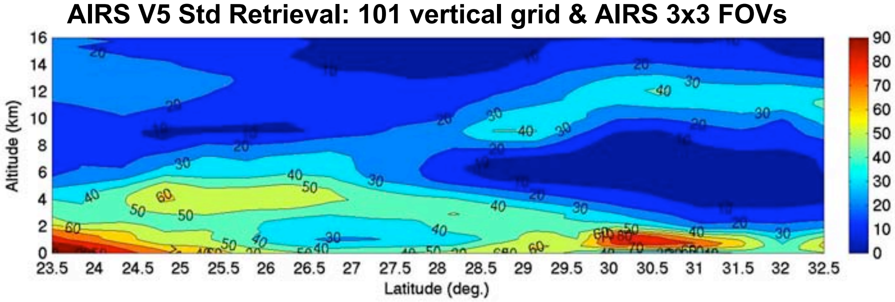


AIRS LaRC Retrieval: 101 vertical grid & AIRS 1x1 FOVs

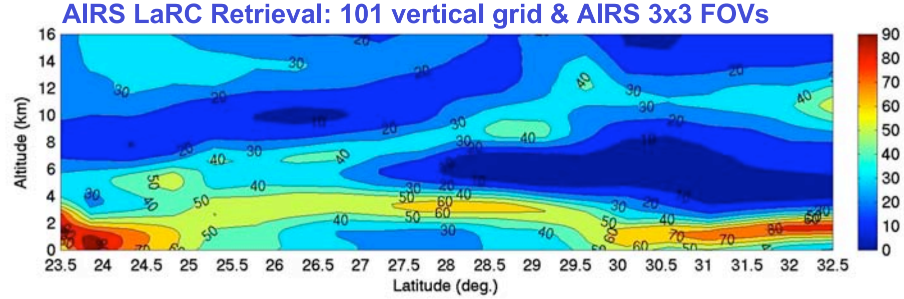


Different Resolution, Same Algorithm

AIRS V5 Std Retrieval: 101 vertical grid & AIRS 3x3 FOVs



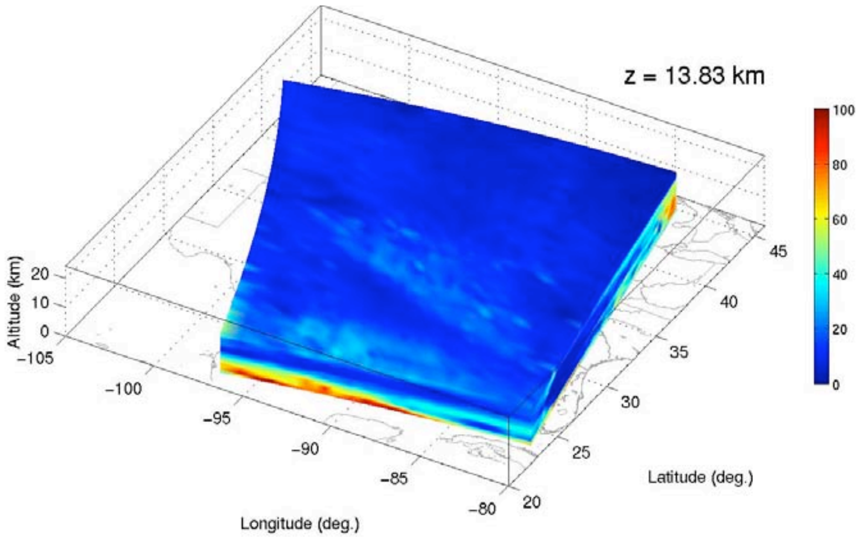
AIRS LaRC Retrieval: 101 vertical grid & AIRS 3x3 FOVs

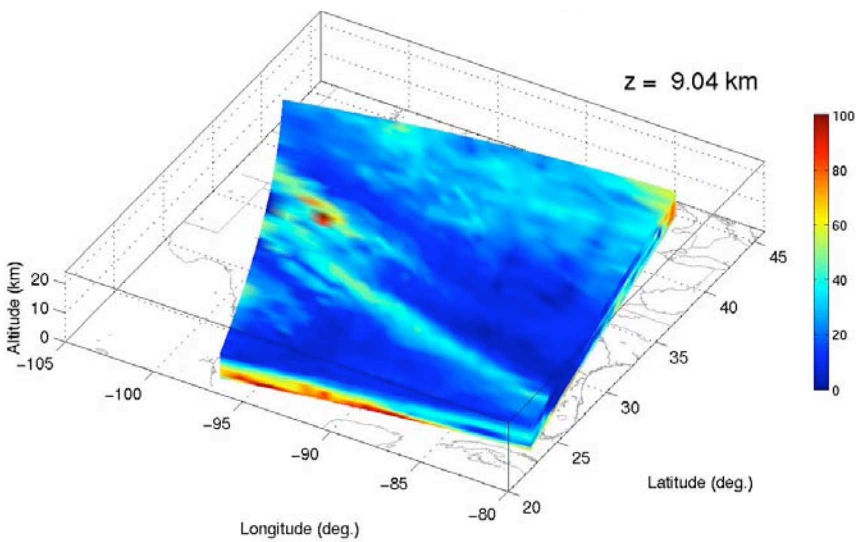


Same Instrument, Different Algorithms

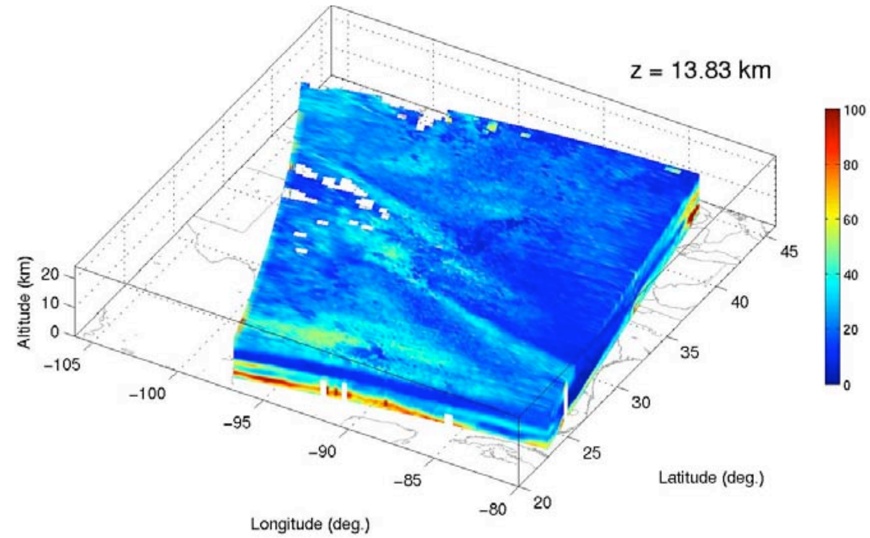
AIRS V5 vs. LaRC (RH Horizontal)

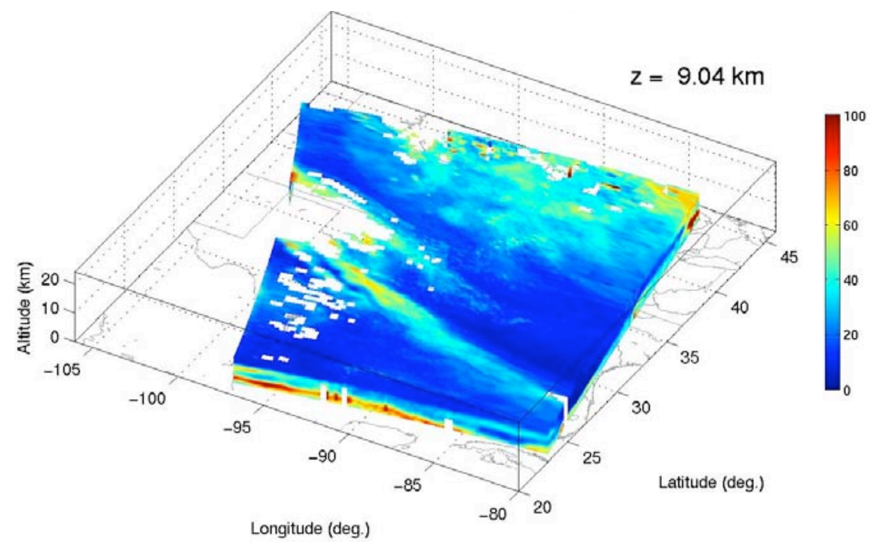
AIRS V5 Std Retrieval: 101 vertical grid & 3x3 FOVs





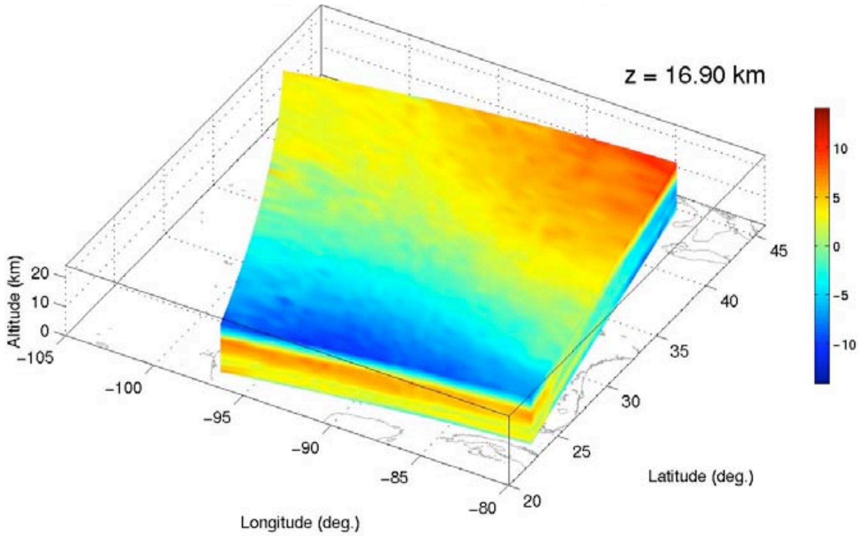
AIRS LaRC Retrieval: 101 vertical grid & 1x1 FOVs

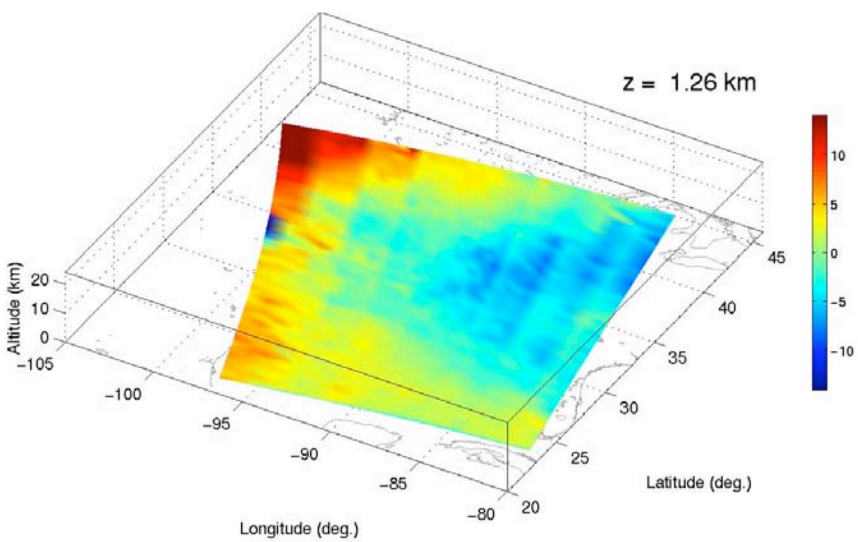




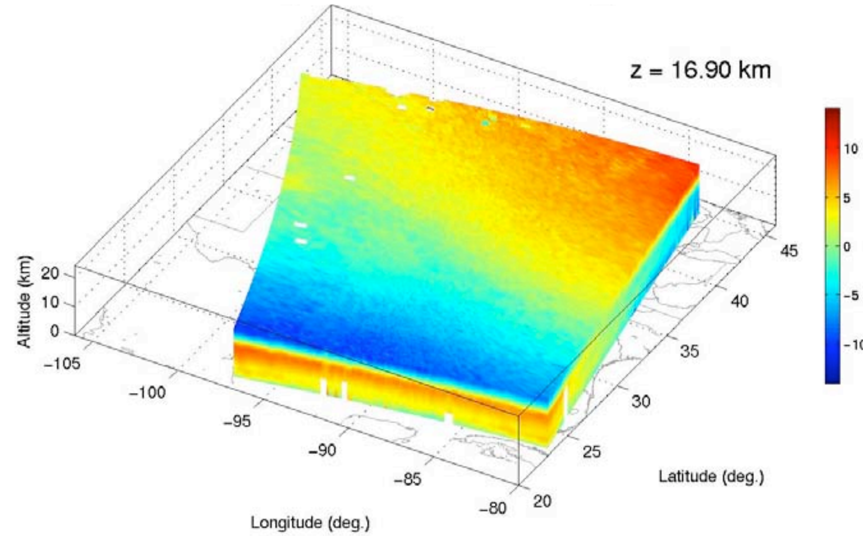
AIRS V5 vs. LaRC (ΔTemp Horizontal)

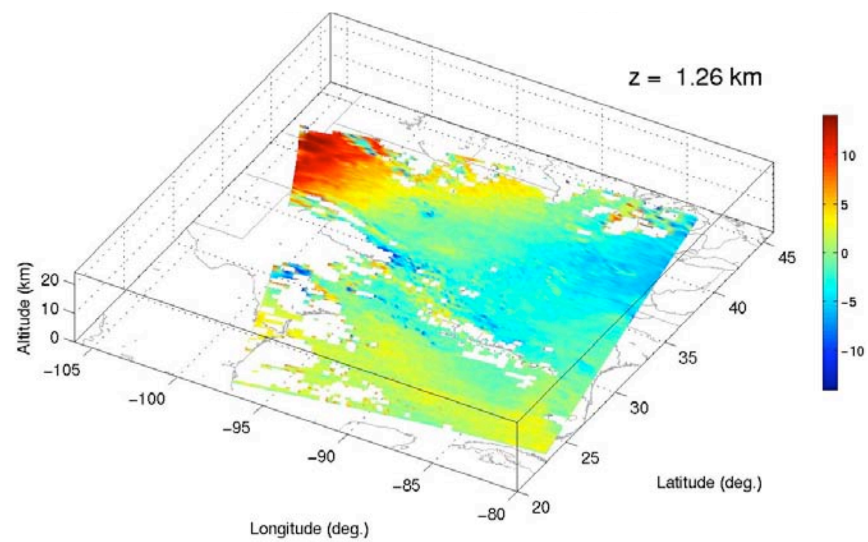
AIRS V5 Std Retrieval: 101 vertical grid & 3x3 FOVs





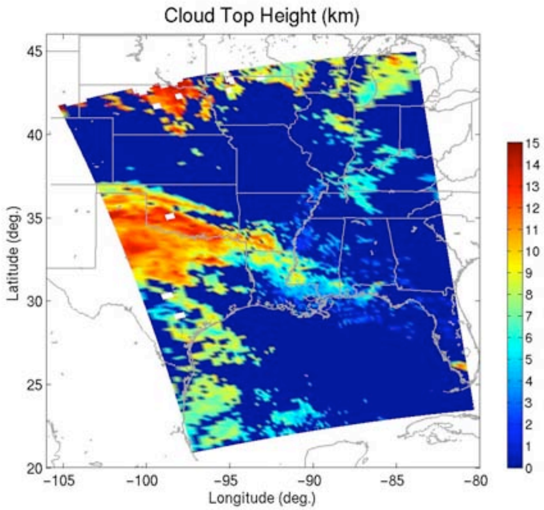
AIRS LaRC Retrieval: 101 vertical grid & 1x1 FOVs

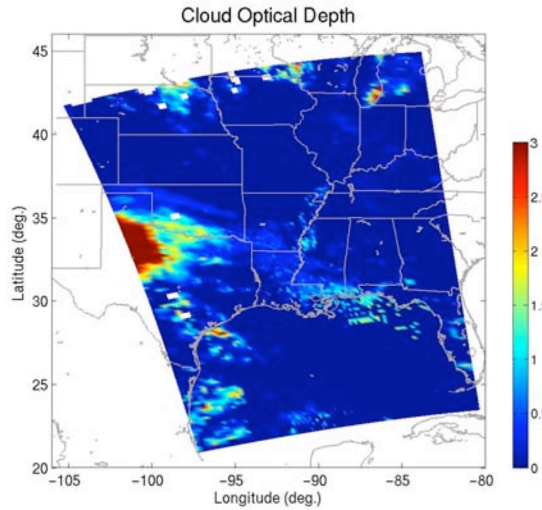


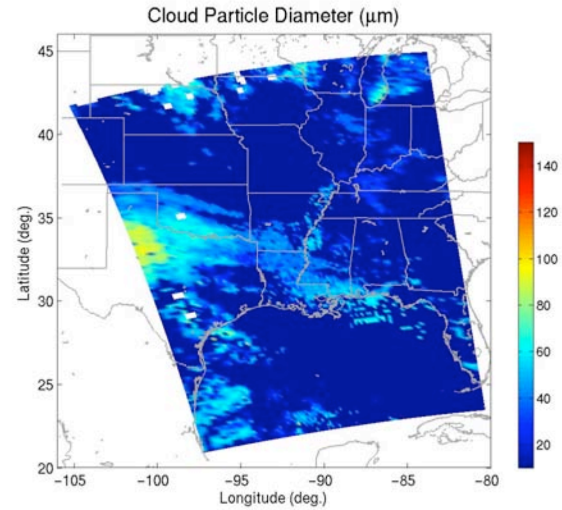


LaRC Retrieval Demo with AIRS: Cloud & Surface

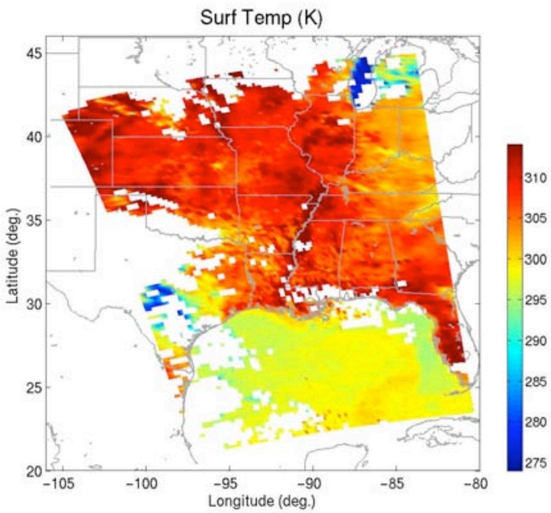
Cloud Parameters:

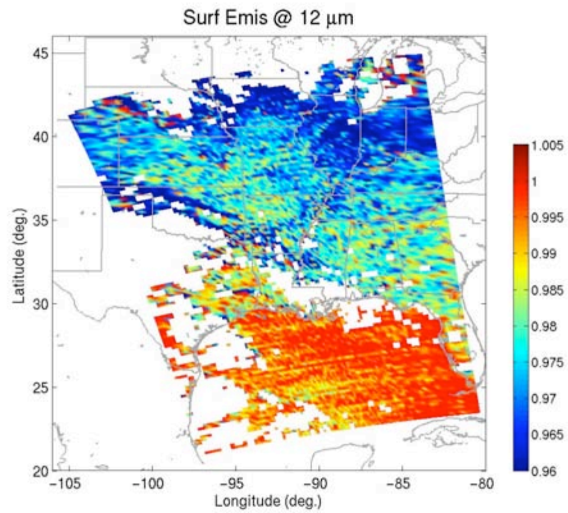


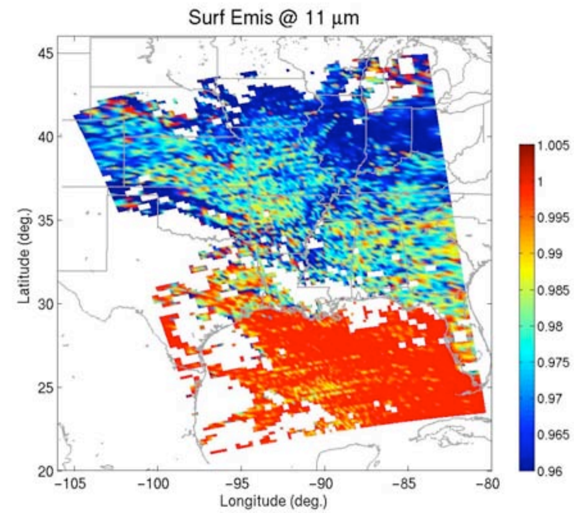




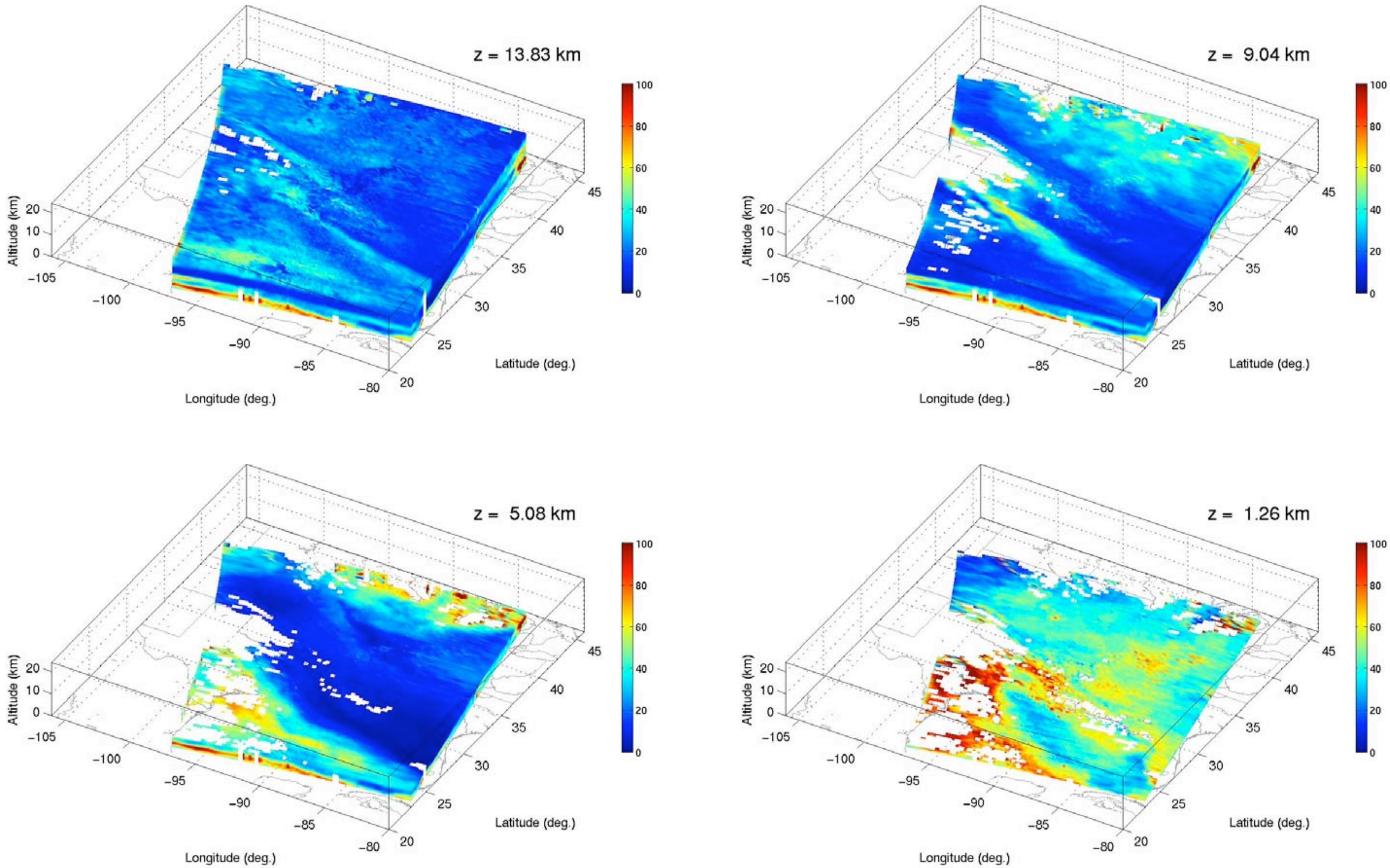
Surface Properties:



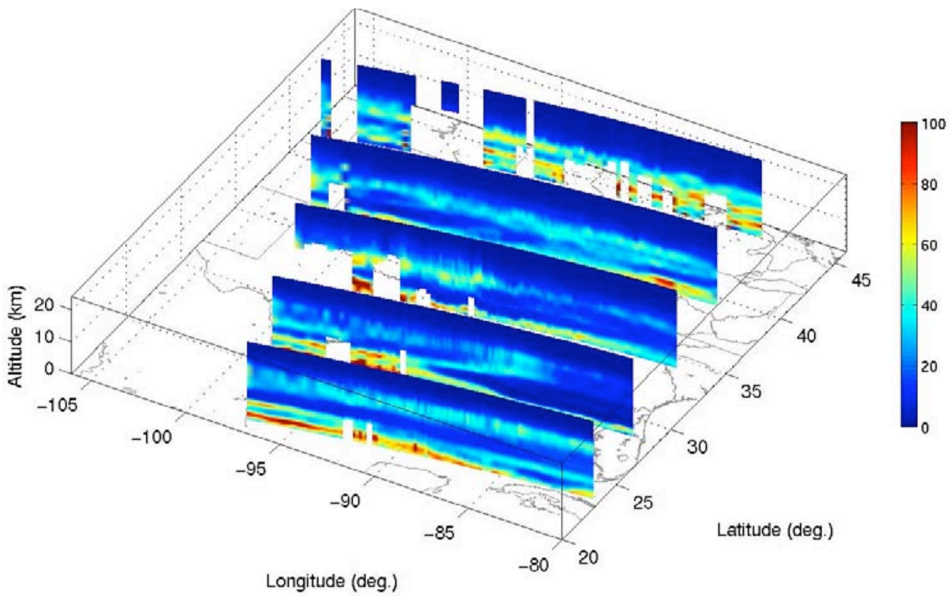


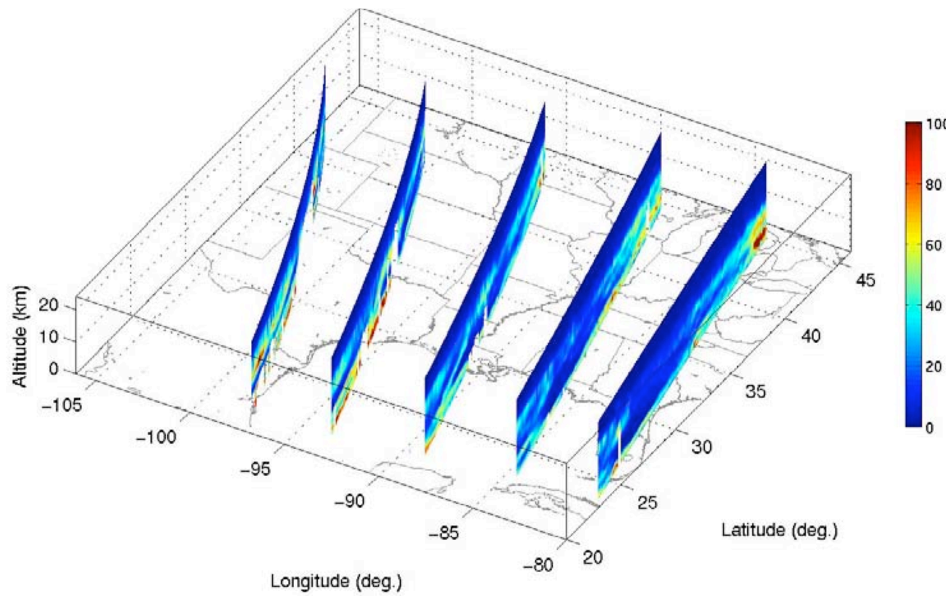


LaRC Retrieval Demo with AIRS: RH Horizontal



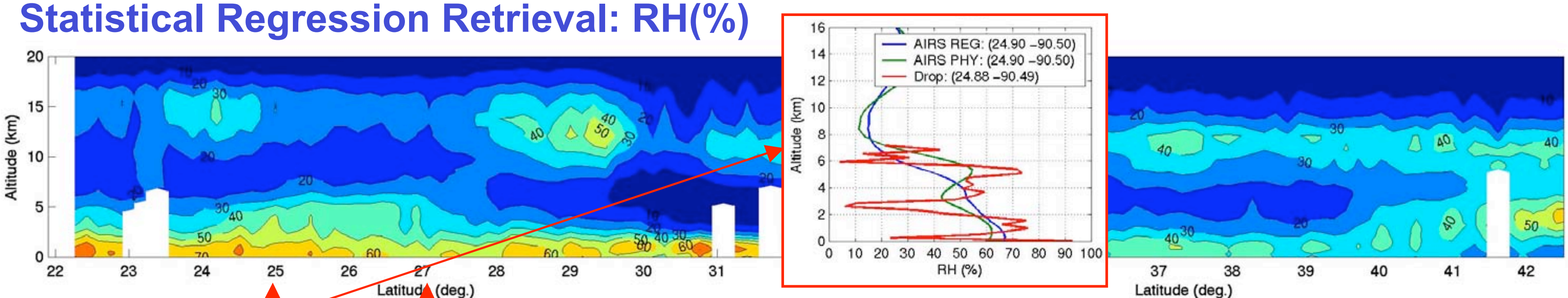
LaRC Retrieval Demo with AIRS: RH Vertical



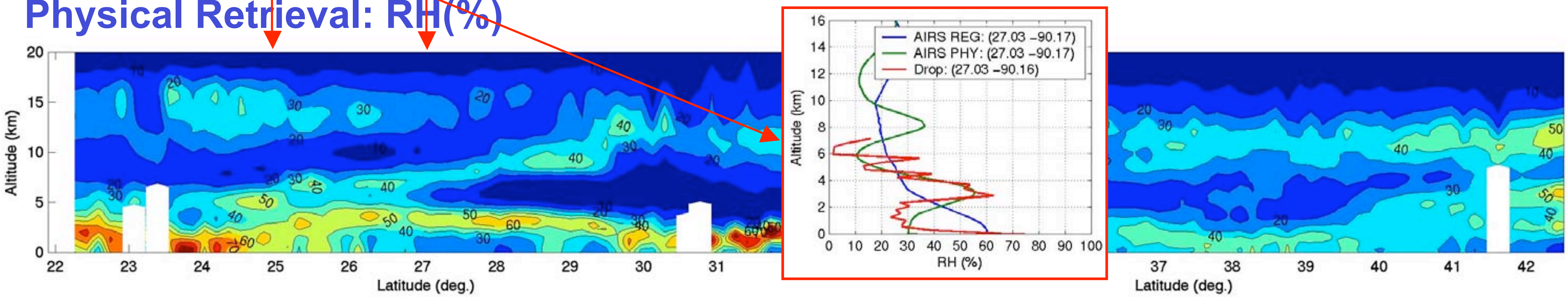


LaRC AIRS Regression vs. Physical Retrieval

Statistical Regression Retrieval: RH(%)



Physical Retrieval: RH(%)



The retrieval improvement based on the EOF statistical regression through physical iteration is only contributed by AIRS measurements as the minimum information methodology used. A high resolution atmospheric structure is captured very well by AIRS measurements (retrievals); not only in the troposphere but also in the boundary layer.

Summary and Future Work…

- Preliminary Case study with AIRS V5 is inter-compared between AIRS and IASI using two different retrieval approaches.
- Coincident dropsondes during the IASI and AIRS overpasses at the same locations are used to validate atmospheric conditions.
- Full resolution retrievals from IASI and AIRS are very similar, however, IASI retrieval seems smoother than AIRS (this might be due to a lower spatial resolution of IASI and/or a "higher" retrieval noise level with AIRS).
- Further inter-comparison between AIRS and IASI with other cases will be performed to provide more-definitive conclusions.
- The benefits of this retrieval validation approach with different retrieval algorithms and instruments are demonstrated.
- AIRS data will be interoperated to IASI FOV for co-located inter-comparison to minimize geophysical location difference.
- Case studies such as this (i.e., use LaRC retrieval algorithm) can be used in validating upcoming AIRS V6 prior to V6 releasing.
- Continue to work with EUMETSAT to improve and to validate IASI operational products.

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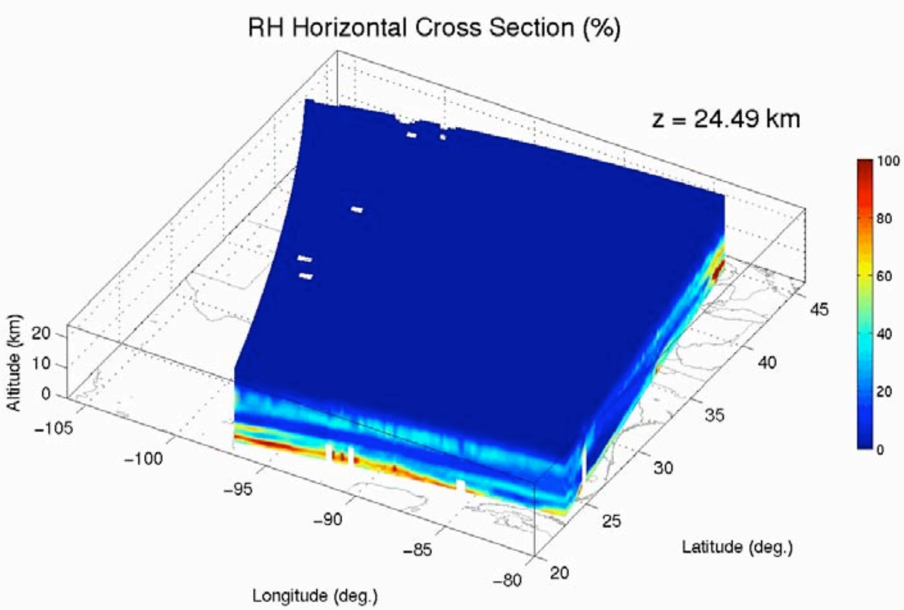
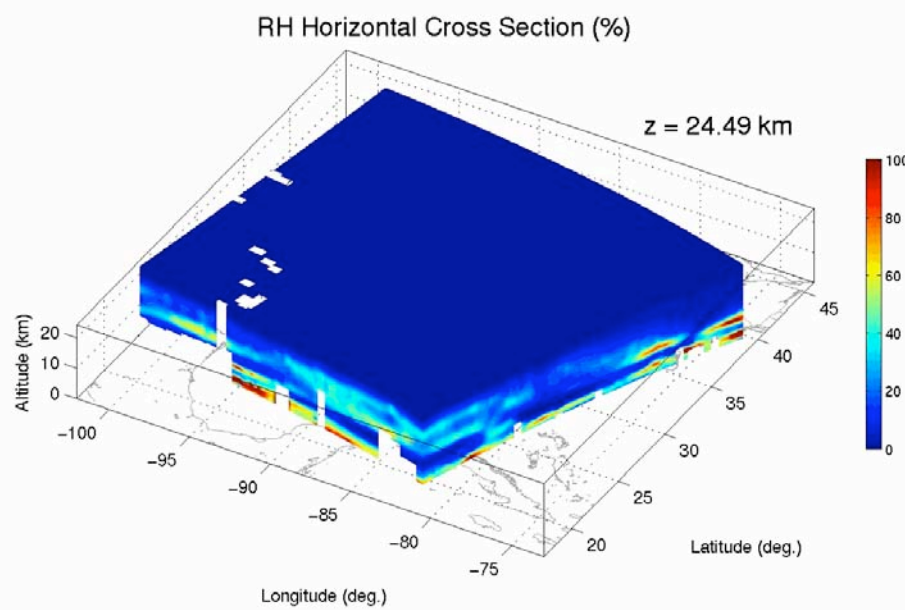
AIRS and IASI RH Distributions (2007.04.29)

AIRS @ ~19:30 UTC

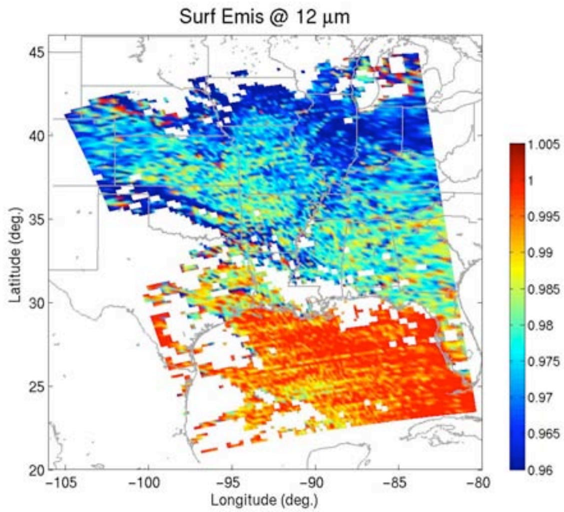


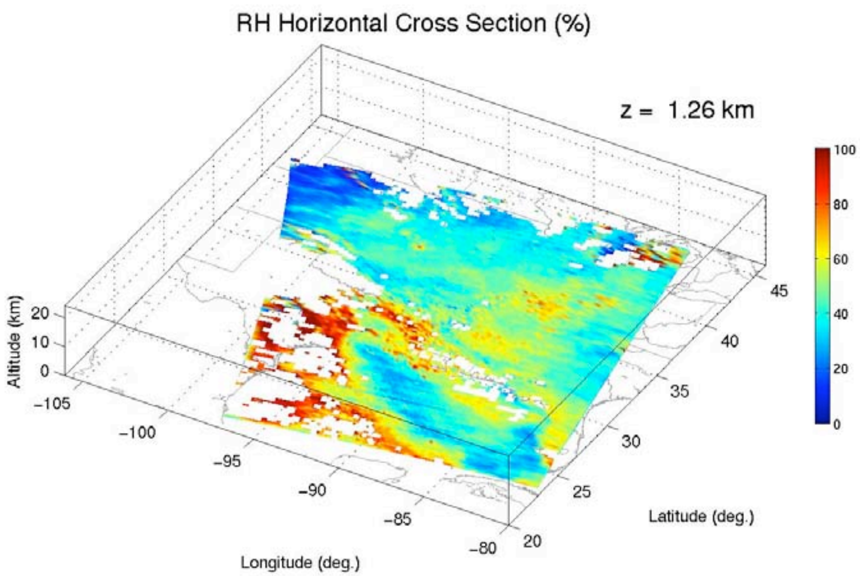
IASI @ 15:45 UTC



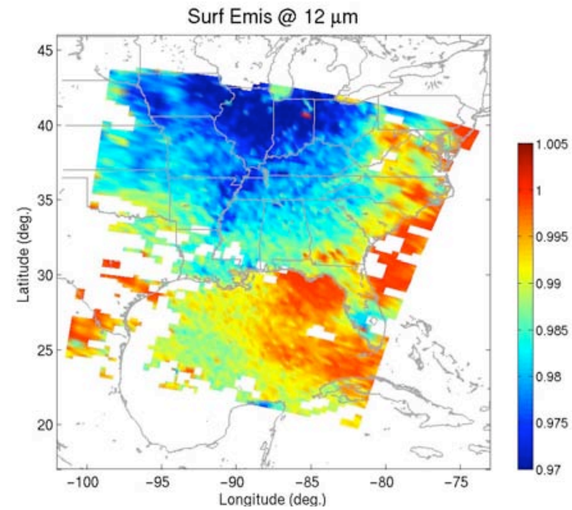
AIRS vs. IASI (for retrieval noise comparison?)

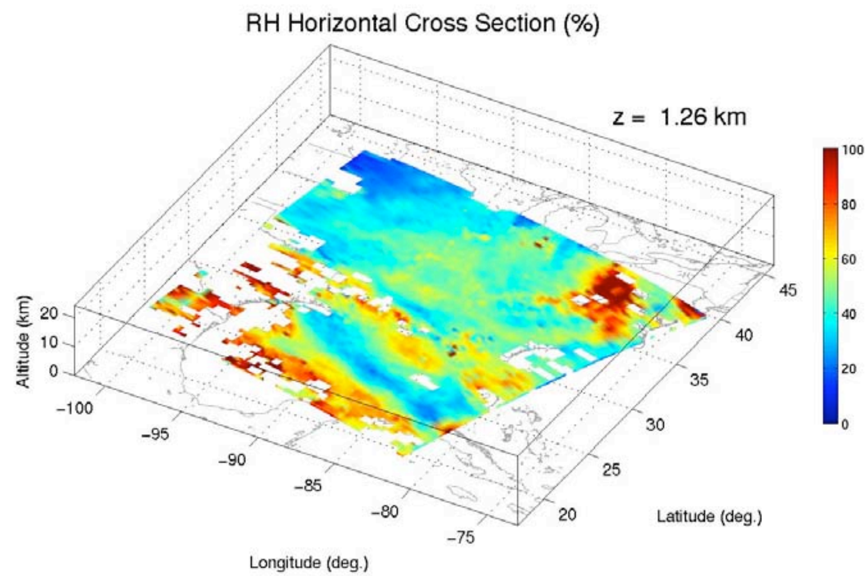
AIRS LaRC Retrieval: AIRS 1x1 FOVs





IASI LaRC Retrieval: IASI 1x1 FOVs





Comparison between IASI and AIRS